Larhyss Journal, ISSN 1112-3680, n°42, Juin 2020, pp. 179-207

OUED M'ZAB'S I.R.S DEVELOPMENT POPULATION AND FLOOD, LIFE IN HARMONY PART 3: THE GENIUS OF FLOODWATER SHARING

L'AMENAGEMENT I.R.S D'OUED M'ZAB LA POPULATION ET LES CRUES, LA VIE EN HARMONIE PARTIE 3: LE GENIE DU PARTAGE DES EAUX DE CRUES

REMINI B.

Department of Water Sciences and Environment, Faculty of Technology, Blida 1 University, Blida 9000, Algeria

reminib@yahoo.fr

ABSTRACT

This paper evokes for the first time, flood management in the Ghardaïa oasis for more than 7 centuries. For this purpose, a hydraulic millennium development was realized by the Mozabites on the M'zab River. During the period: 1996-2020 we carried out several missions at the rate of two to three per year. Investigations and inquiries were carried out with the Ksourian population and the Oumana El Ma (water management committee). The M'zab River was laid out in three ways, which is the originality of the IRS Development. This gives priority to irrigation followed by recharging of the water table and the security of the oasis. This study shows that the IRS Development contains two seguias intended for irrigation. It is the seguia of Bouchemdjane to irrigate the upper part of the palm grove - East of Ghardaïa. The Tardja N'Takdimt is intended for the irrigation of the lower part of the palm grove - East of Ghardaïa.

Keywords: M'zab River, Flood, Irrigation, East Palm Grove, IRS Development, floodwater sharing.

RESUME

Le présent papier évoque pour la première fois, la gestion des crues dans l'oasis de Ghardaïa depuis plus de 7 siècles. A cet effet, un aménagement hydraulique millénaire a été mis en œuvre par les Mozabites sur l'oued M'zab. Durant la période : 1996-2020 nous avons effectué plusieurs missions à raison de deux à trois par année. Des investigations et des enquêtes ont été menées auprès de la population ksourienne et les Oumana El Ma (comité de gestion de l'eau). L'oued M'zab a été aménagé en trois voies tel est l'originalité de l'aménagement IRS. Celui-ci donne la priorité à l'irrigation suivi de la recharge de la nappe phréatique et de la sécurité de l'oasis. Il ressort de cette étude que l'aménagement IRS contient deux seguias destinées à l'irrigation. Il s'agit de la seguia de Bouchemdjane pour irriguer la partie haute de la palmeraie –Est de Ghardaïa. Tardja N'Takdimt est destinée à l'irrigation de la partie basse de la palmeraie –Est de Ghardaïa. Tout un réseau de partage des eaux a été réalisé dans la palmeraie-Est de Ghardaïa. Il est équipé de seguia-ruelles et des ouvertures au bas du mur de chaque jardin pour permettre aux eaux de crues d'inonder la palmeraie-Est de Ghardaïa ; c'est l'originalité de la palmeraie de M'zab.

Mots clés : Oued M'zab, Aménagement IRS, Crue, Irrigation, Palmeraie Est, Partage des eaux de crues.

GLOSSARY

Amlaga: Meeting point of two Rivers
Chaabat: Tributary
Khottara: Animal-drawn well
Koua: Realized rectangular opening in the wall of a garden
N': of
Tardja: open channel
Oumana El Ma: Management Committee
Oumana Esseil: Management Committee
Ahbas: Dam
Rosfa: Rising of 5 to 10 cm placed before an opening.
Seguia: open channel
Tissanbadh: Underground gallery

INTRODUCTION

Raws, floods, two scary words. Often the flood when it occurs in arid regions, it causes material and human damage. Flash floods have increased in number in recent years, especially in the early fall. This phenomenon often occurs in the arid regions of the Algerian Sahara. However, often the population of the north perceives the floods as a misfortune; conversely the Mozabites consider the floods as a gift from the sky. Only the Mozabite population who can speak to the flood. For her, the flood was never a danger, you only have to live higher and cultivate the wadi. A submersion of the palm grove by one to two floods per year is essential for its development. The waters of a flood are loaded with clay particles and nutrients that are beneficial to the plant. Also, the arrival of a flood causes a general leaching of the palm grove while sweeping away the quantities of salts accumulated during one to two years. The only reservoir available in the M'zab Valley was the water table. Its recharge by flood water infiltration once or twice a year becomes essential to ensure permanent irrigation of 5 to 7 years of drought. So how do you take advantage of the flood? To answer this question, hydraulic installations were carried out in the oases of the M'zab valley which we called: IRS development. In each oasis, there is an IRS Development specific to the geomorphology of the environment. This is how we find that the studies we conducted on the oases of Metlili, El Guerrara, Berriane and Ghardaïa Est (Remini, 2020; Remini, 2019; Remini, 2018; Remini and Ouled Belkhir, 2019; Khelifa and Remini, 2019). This study follows that on the Touzouz River (Remini, 2020). This paper addresses the greatest IRS Development project carried out on the river for irrigation the Est palm grove of Ghardaia. In part 3 of the study: "IRS Development of M'zab River", we examine the sharing of flood waters between the gardens of East palm grove of Ghardaia.

STUDY REGION AND SURVEYS

Study area

The study area is the Ghardaïa oasis; capital of the M'zab valley. A city with a tourist vocation par excellence. Very well known for its millennial Ksourian architecture. Located 600 km southwest of Algiers, Ghardaïa sits today on one of the largest aquifers on the planet. This is the tablecloth of the Intercalary Continental (fig. 1). Before the discovery of the aquifer of Intercalary Continental in the early 1940s, the entire M'zab valley was fed by the water

table. Unfortunately, today the waters of this aquifer are polluted. The Ghardaïa oasis has today become a large metropolis where there is a great commercial, agricultural and tourist activity. Ghardaïa is crossed by the M'zab River, well known for its devastating floods. With a flow exceeding 1200 m^3/s, the 2008 flood caused a lot of material and human damage (Ouled Belkhir and Remini, 2016, Bouamer et al, 2019; Zegait et al, 2018; Remini et al, 2012).

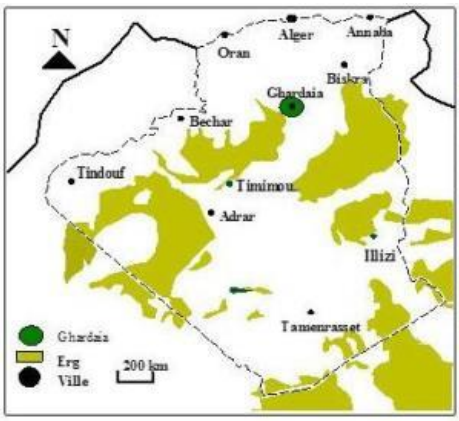


Photo 1. A view of the M'zab valley (Remini, 2020)

Photo 2. A view of the legendary Ghardaïa market (Remini, 2018)

Figure 1: Situation of the study region (Remini, 2020)

Methodology of work

Ghardaïa; a rocky region with a hyper-arid climate known for low rainfall and a temperature that can exceed 50°C in summer. In M'zab River, sporadic floods occur once or twice a year but which can drain significant amounts of water. Make a development in the M'zab River to annihilate the floods and make the most of these waters loaded with solid particles.

Interested in the floods in M'zab River in the early 2000s, once on site we were impressed by the extent of the development carried out over the past 7 centuries. We liked a city and everything that the Ksourian population has achieved in terms of hydraulics. With each mission, we discover new elements of the layout. This is how this work lasted until 2020.

RESULTS AND DISCUSSIONS

Principle of the IRS Development of M'zab River

The I.R.S Development consists in annihilating the floods of M'zab River and making the most of these waters. In this case, the flood is divided into 3 parts depending on the priority: Irrigation, Recharge of the water table and the evacuation of excess water to the River (Security) (fig. 2). The IRS Development in Ghardaïa gives priority to the irrigation of the palm grove with raw water. Once all the gardens are well watered, the excess of the flood is directed towards the Bouchen reservoir in order to replenish the water table. If the flood still persists, the excess water will be evacuated by the downstream drain in the M'zab River. Thanks to hundreds of animal-drawn wells (Khottara), located in the eastern palm grove of Ghardaïa, the water infiltrated during floods will be used for permanent irrigation during the dry period.

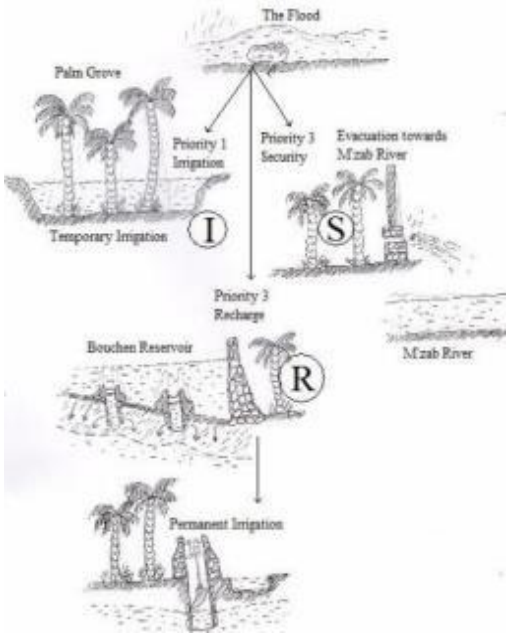


Figure 2: IRS Development concept (Schema, Remini, 2020)

Covering an area of 200 ha, the ancient palm grove of Ghardaïa stretches from Ahbas Ajdid to Ahbas N'Bouchen (from south to north). M'zab River divides the palm grove into two equal parts: East and West. The West palm grove with an area of 100 hectares is irrigated with untreated water flooding of Touzouz

River. As for the East palm grove with an area of 100 hectares is irrigated with untreated water flooding of M'zab River (Fig. 3 and 4). The IRS Development gives priority to temporary irrigation (raw water irrigation). To this end, an adequate arrangement has been designed so that the flood waters reach all the gardens of the palm grove of Ghardaïa. Upstream from the palm grove, two seguias: Bouchemdajne and Takdimt were specially made to transport the floodwaters from M'zab River to the palm grove. A flood water sharing network has been created inside the palm grove composed of seguia-lanes to distribute the flood waters between all the palm grove

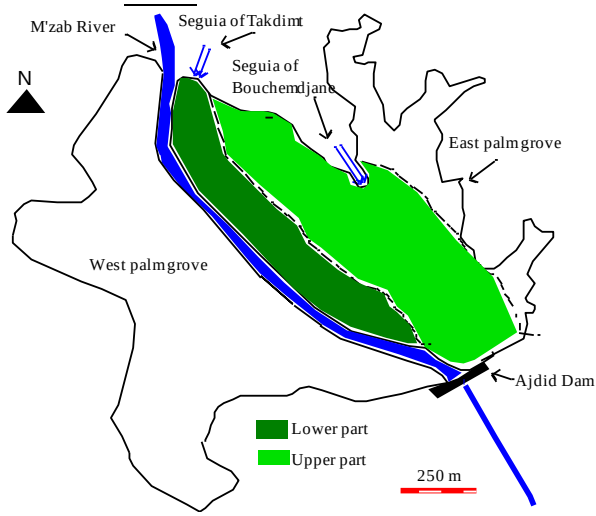


Figure 3: Delimitation of the old palm grove of Ghardaïa (Schema, Remini, 2020)

Figure 4: A view of the eastern palm grove (Photo. Remini, 2018)

The sharing of flood water, what genius?

The M'zab valley, the only region in the Sahara that has a network for sharing raw flood waters. This is proof of the interest shown by the Mozabite population in this type of irrigation. Original and unique in the world, the method of sharing flood waters in the Ghardaïa oasis is the same throughout the M'zab valley. The principle is the submersion of all the gardens of the palm grove by the waters loaded with fine particles from the flood. To this end, a distribution and sharing network for rainwater has been developed by the Mozabite population. As we mentioned at the beginning of this paper, the irrigation of the western palm grove of Ghardaïa is taken care of by the IRS development of the Touzouz River (Remini, 2020). However, the eastern palm grove of Ghardaïa is supplied with flood water from the Bouchemdjane seguia for the upper part and the seguia (fig. 5). As for the lower part of the eastern palm grove, Tardja of Takdimt is responsible for its irrigation (fig. 6). Only, priority is given to the irrigation of the upper part since its surface represents 75% of the total irrigated surface. To this end, five galleries were designed to convey the waters of the Bouchemdjane seguia from Tissanbath to the network. On the other hand, the lower part, which represents 25% of the total irrigated area, is supplied by a single gallery which transports the waters of the Tardja Takdimt.

Figure 5: A view of the Tardja N'Bouchemdjane (Photo. Remini, 2018)

a)

Figure 6: A view of the Tardja N'Takdimt (Photo. Remini, 2018)

Given, the irrigated area of the upper part of the eastern palm grove of Ghardaïa is greater than that of the lower part, priority is given to irrigation by the waters of the seguia of Bouchemdjane (the upper part of the eastern palm grove). This is how the Tissanbath system (underground galleries) of the seguia of Bouchemdjane is composed of 6 underground galleries. On the other hand, the Tissanbadh system of Tardja N'Takdimt contains a single underground gallery.

Irrigation of the upper part of the East palm grove of Ghardaïa

For the upper part of the eastern palm grove, water sharing begins once the flood water arrives at the regulation dam (the Tissanbadh entrance) (fig. 7(a et b)), the dam with a length of 20 meters fitted with 36 rectangular openings which are fitted with sliding valves. It is the most important hydraulic structure of this ancestral development. The 36 openings are equipped with sliding rocky flat slabs (today are made of steel) which, once irrigation is completed or to avoid flooding in the palm grove, the openings will be immediately closed.

a) In the absence of floods (Photo. Remini, 2020)

b) During floods (Photo. Heritage of M'zab)

Figure 7: A general view of Tissanbadh

Once the 36 openings of the regulation dam (Tissabadh entrance) have been crossed, they are distributed through the 6 underground galleries of different sections and flow towards the eastern palm grove of Ghardaïa (fig. 8 and 9). Tissanbadh openings help regulate floodwater and reduce flow energy before entering the galleries. Each drain is sized according to the flow to be conveyed for the irrigation of the gardens. The flow of each gallery depends on the number of palm trees to irrigate. In reality there are 5 underground galleries out of the 6 that have been operational for more than 7 centuries. The sixth gallery, which was used to irrigate the Chaabet Noundja palm grove, never worked (fig. 10 and 11). The project of digging the drain at the bottom of the rock massif has not been completed. Only, more than 40% of the excavation of the gallery was carried out during 40 years of intensive work with rudimentary material means.

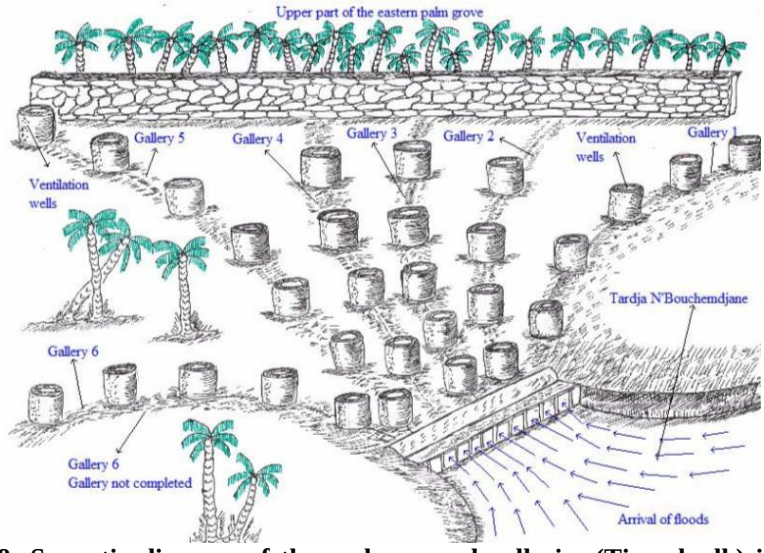


Figure 8: Synoptic diagram of the underground galleries (Tissanbadh) intended for the irrigation of the upper part (Bouchemdjane) of the palm grove - East of Ghardaïa (Schema Remini, 2018)

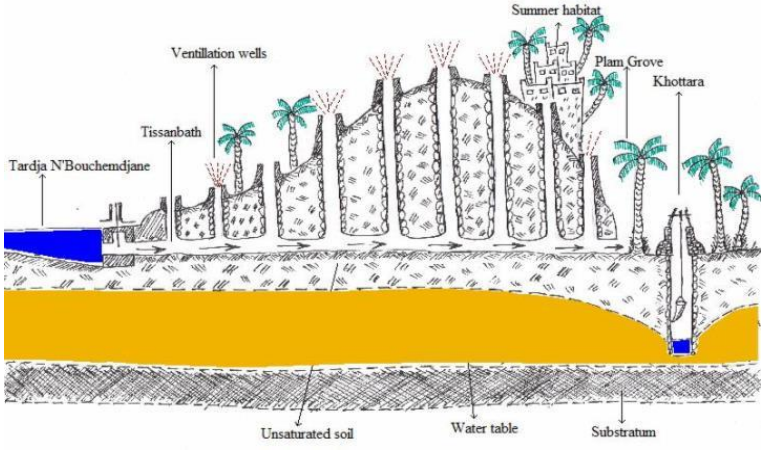


Figure 9: Diagram of a longitudinal section of an underground gallery in the upper part of the eastern palm grove of Ghardaïa (Schema Remini, 2018)

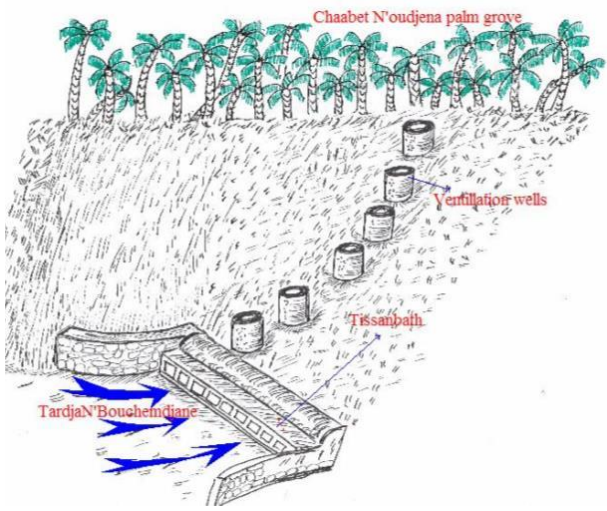


Figure 10: Synoptic diagram of the unfinished gallery intended for the irrigation of the palm grove of Chaabet Noundja (Schema Remini, 2018)

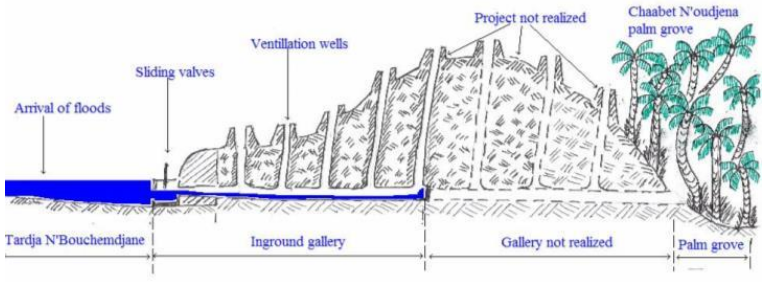


Figure 11: Synoptic diagram of the longitudinal section of the unfinished gallery (Schema Remini, 2018)

Equipped with 38 ventilation shafts that can reach 40 meters deep, the galleries of the Ghardaïa foggaras have different section shapes (figs. 12 and 13). We observe rectangular, triangular and complex sections. The galleries were designed in such a way as to prevent the walls from bursting and the deposit of silt during the flow of high flows. Vertical wells, 38 in number, are drilled vertically on the roofs of the galleries, which have the role of ventilating the pipes to keep a free surface flow and thus prevent the canals from bursting during floods. They also allow access to the gallery for maintenance of the structures (fig. 14 and 15).

Figure 12: A triangular gallery draining the floodwaters of the Bouchemdjane seguia towards the sharing network (photo. Remini, 2014)

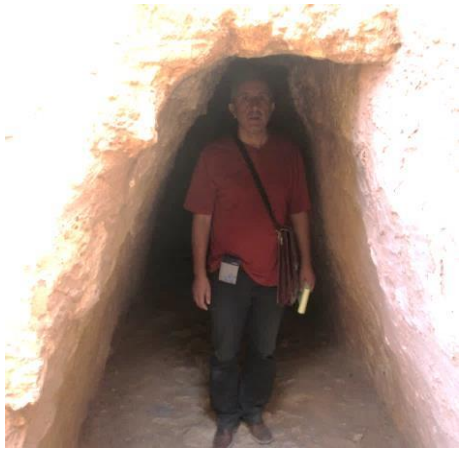


Figure 13: Galleries over 1.5 meters high carved out of hard rock (photo. Remini, 2013)

Figure 14: A view of the ventilation shafts of the galleries (Tissanbadh N'Bouchemdjane) in Ghardaïa (photo. Remini, 2010)

Figure 15: Galleries ventilation well (Tissanbadh N'Bouchemdjane) which can reach 40 m deep (photo. Remini, 2010)

The galleries communicate with each other in a place located 100 m downstream from Tissanbath in a corridor placed vertically at the five galleries which allows water to be distributed between the galleries. For example, a gallery can arrive carrying a strong flow from the dike (Tissanbath), but at the arrival of this point, the water is evacuated in the other neighboring galleries (fig. 16). In addition these channels have been designed in such a way as to avoid the deposit of sand in the channels: steep slope and change of section.

Figure 16: A distribution point of the waters inside the Galleries (Tissanbadh N'Bouchemdjane) (photo. Remini, 2013)

Before reaching the gardens, the flood waters of M'zab River flow into the seguia of Bouchemadjane. Arriving at the entrance to the upper part of the eastern palm grove, the waters of the Bouchemadjane seguia rush into five underground galleries (Tissanbadh of Bochemdjane). At the end of the galleries of different sections (rectangular, triangular and horseshoe), the waters communicate directly with the seguias-alleys of the sharing network (fig. 17).

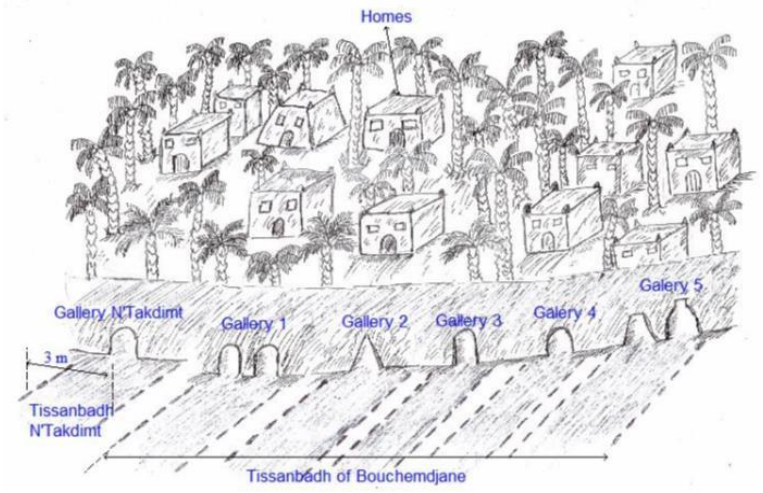


Figure 17: Sketch of the five Tissanbath exits (underground galleries) (Remini diagram, 2020

Of the five galleries, two have a double opening (exits 1 and 5) (fig. 18 (a and e)). On the other hand, the galleries (2, 3 and 4) have only one outlet (fig. 19 (b, c and d)). This depends on the area of the gardens to be irrigated. Each gallery

supplies a defined number of districts. The distribution network is designed so that a garden is irrigated by water from a single gallery.

a) Exit from gallery 1

b) Exit from gallery 2

c) Exit from gallery 3

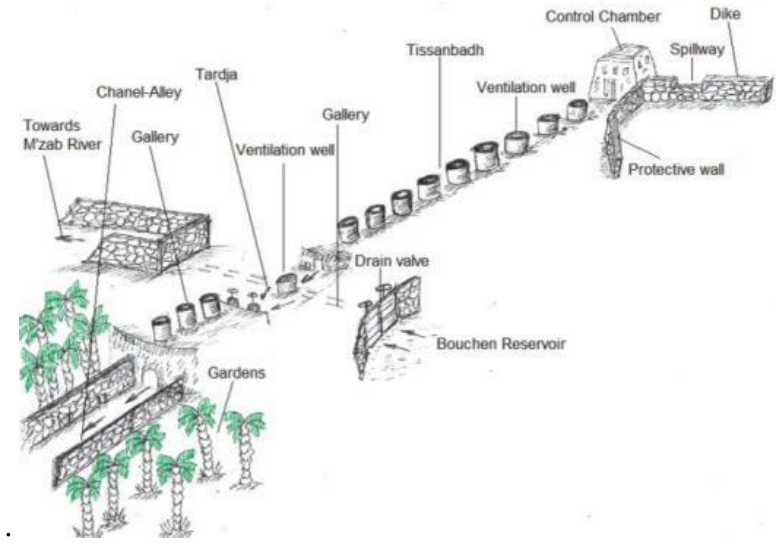
d) Exit from gallery 4

e) Exit from gallery 5

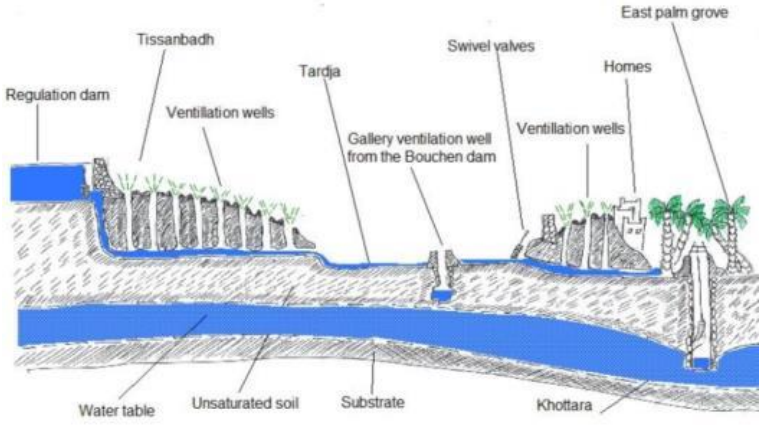
Figure 18: Exits from the galleries (Tissanbadh) of Bouchemdjane (Photo. And Diagram Remini, 2014)

Irrigation of the lower part of the eastern palm grove of Ghardaia

As we mentioned at the beginning of this paper, the irrigation of the lower part of the palm grove takes place after the irrigation of the upper part of the eastern palm grove. After passing the first regulating dam, the flood water drained by the seguia of Bouchen is stored in the second riprap dam, 77 m long and 1.5 m high. The dam is equipped with a weir and drainage outlets composed of 6 sliding valves. This water is intended either for irrigation or for groundwater recharge. According to the IRS development, priority is given to the irrigation of the lower part of the eastern palm grove of Ghardaïa. To this end, the valve operations allow water to flow into the seguia of Takdimt. The latter is composed of an underground gallery 180 m long (equipped with 9 vertical wells 3 m deep and 1 m in diameter) and an open channel 1200 m long and 3 m wide (fig. 19 (a and b)). Arriving at the entrance to the lower part of the eastern palm grove, the waters of the Takdimt seguia rush into the underground gallery (Tissanbadh of Takdimt) (fig. 20 (a and b))

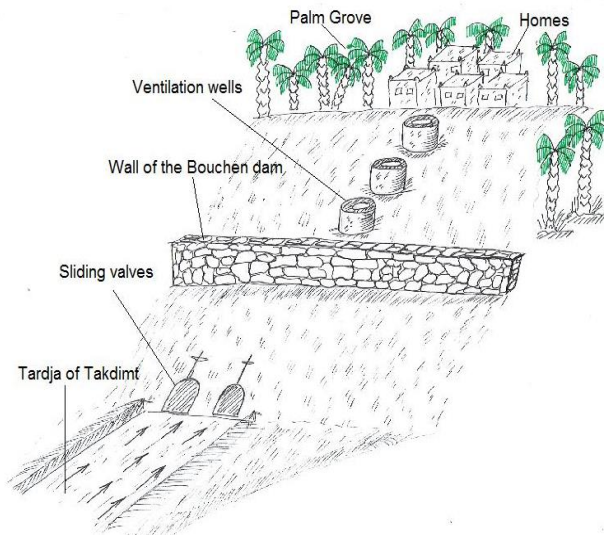


a) Overview

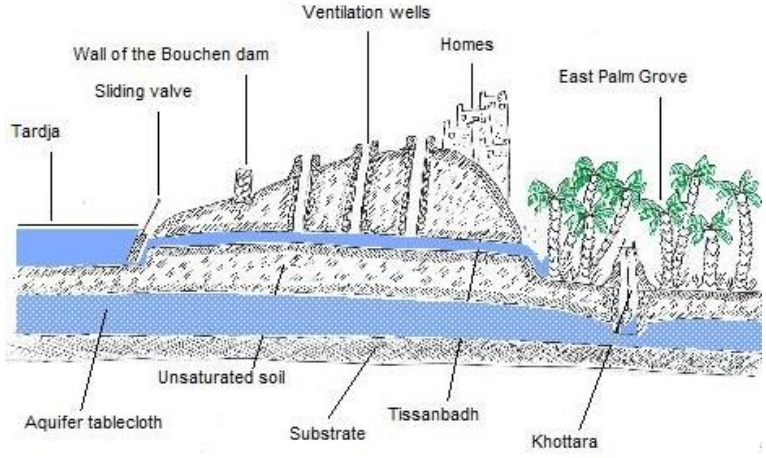


b) View of a longitudinal section

Figure 19: Diagram of Tardja N'Takdimt and Tissabadh (gallery) (Schema Remini, 2020)



a) General view



b) Coupe longitudinale

Figure 20: Tissabadh (gallery) N'Takdimt fitted with two sliding valves (Schema Remini, 2020)

Tissanbadh N'Takdimt (horseshoe section gallery) which has two openings is equipped with two sliding valves to control irrigation (fig. 21). At the exit of the 50 m long gallery equipped with 3 aeration wells, the waters communicate directly with the seguias-alleys (fig. 22).

Figure 21: The entrance to Tissanbadh N'Takdimt - Sliding valves (Photo. Remini, 1998)

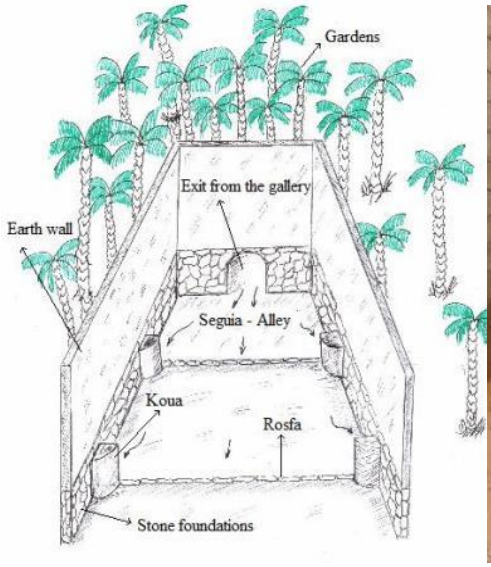


Figure 22: Exit from the gallery (Tissanbadh) N'Takdimt (Photo. Remini, 2014)

Once the irrigation operation is completed, the two valves can be closed and the water will be directed towards the filling of the Ahbas of Bouchen reservoir in order to recharge the water table. With a total length of 1400 m, Tardja of Takdimt can drain an estimated flow of 300 l/s.

Flood water sharing network in the eastern palm grove

The network for sharing the flood waters of the palm grove - East is made up of ten kilometers of seguias-alleys with a section of width varying from 1 to 3 meters depending on the type of seguia: main or secondary. This network has been well sized. To a main irrigation channel, its width was determined based on the sum of two donkey's well loaded circulating one beside the other. On the other hand, a seguia is of secondary type if its width is equal to a single donkey well charged circulates freely. The banks of these open canals are delimited by the walls of the gardens. Built in the ground on a foundation stone of 0.8 m in height, the walls may reach a height of 2 m (Fig. 23).

Figure 23: The typical wall of the gardens of a palm grove in the M'zab Valley (Photo. Remini 2009)

For security reasons, all the garden walls have been built in the same way. Nobody had the right to contradict such a regulation emanating from the Djamaa (committee of the wise). For Mozabites, the threshold for the size of a flood has been set at 80 cm in height, an estimated flow of 2 m^3/s for a main lane. It is no coincidence that the height of 0.8 m is repeated for the distribution wall of the M'zab River (Remini, 2020). The purpose of such urbanization is in the event of a major flood or the flow in the network exceeds the threshold (i.e. the height of the foundations), the earth wall collapses under the action of the waters which flood all the gardens. In reality, the height of the seguia - alley corresponds exactly to the height of the foundation, ie 0.8 m. Figure 24 clearly shows the flow in the seguia lane after a recession. The earthen walls of the gardens collapsed under the action of water.

Figure 24: Collapse of garden walls under the action of water (Photo. Patrimoine de M'zab)

This type of channel has a dual function. It plays the role of an alley for the circulation of the population and animals in periods of drought and of a seguia in times of floods for the flow of water. Some seguia-alleys are equipped with a frontal elevation to allow the population to circulate during floods (fig. 25).

Figure 25: Seguia with a frontal elevation for the circulation of the population in period of flood (Photo. Remini, 2013)

As we mentioned at the beginning, that every garden has the right to a share of water. For this purpose, the garden is provided with a single opening to allow the flood to flood the garden. These rectangular openings have been fitted at the bottom of each garden wall. The opening is placed exactly in the foundation part tangential to the wall and perpendicular to the flow. This opening is called "Koua" by the Mozabites. The Koua is a rectangular opening in dimensions

depending on the size of the garden (number of palm trees and the area of the garden) (fig. 26).

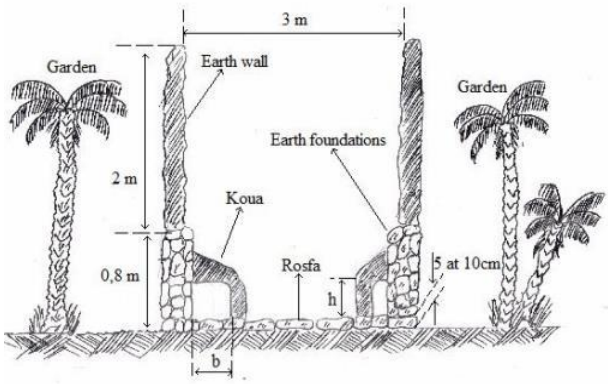


Figure 26: Diagram of the location of a Koua in a seguia (Schéma, Remini, 2020)

The height of the Koua does not exceed the height of the seguia (which is about 80 cm). On the other hand, the width of the Koua must not exceed 30% of the width of the seguia (fig. 27 (a and b)). Generally this case corresponds to a Koua which is intended for the irrigation of more than 3 gardens.

a) Koua for a large flow

b) Koua for a low flow

Figure 27 : La Koua: the originality of the palm grove of the M'zab valley (Photo. Remini, 2011)

The flow in a Koua obeys two laws. In case the water height is lower than the height of the Koua, there is a flow on the rectangular weir. Water flow obeys the law:

$$Q = .m.\, b\sqrt{2g}.h^{3/2}$$

Q: Flow entering by the Koua (m^3/s)
b: width of the Koua (m)
m: Coefficient of flow which depends on the shape of the weir
h: water height (m) less than 0.8m.
In the case where the height of water in the seguia is greater than the height of the Koua (Koua submerged by water), there is a flow by orifice. The flow is given by the relation:

$$Q=S_O.\, C_d.\sqrt{2gh}$$

Q: Flow entering by the Koua (m^3/s)

C_d: Coefficient of the flow which depends on the form of the Koua

S_O: Koua section (m^2)

h: water height (m)

Hundreds of Koua of different sizes have been set up in the distribution network of the East palm grove, showing the originality of a Mozabite palm grove (fig. 28). Each garden receives its share of runoff across the Koua. This flow of water replenishes the aquifer through the recharge wells installed in the gardens. In addition, flood water is very loaded with fine particles and nutrients which allow the soil to be amended once or twice a year and are also of great benefit for palm trees.

Figure 28: Three Koua of different dimensions (Photo. Remini, 2012)

A cut stone threshold 5 to 7 cm high was placed in the seguia next to the opening and perpendicular to the direction of flow to allow water to flow easily into the Koua and reach the garden. Called Rosfa, this threshold plays the role of a rectangular weir and causes a lifting of the sheet of water facilitating the flow through the orifice. It also makes it possible to measure the height of water and therefore to evaluate the irrigation flow rate of each garden (fig. 29).

Figure 29: A Koua with the Rosfa in an alley of the palm grove-East from Ghardaia (Photo. Remini, 2006)

A total of six underground galleries supply flood water to the gardens of the palm grove-East of Ghardaïa (upper and lower parts). Taking into account the slope of the palm grove soil, six irrigation zones have been demarcated. Everything was well planned by the Mozabite population. Each gallery depending on its flow irrigates a number of well-defined gardens. That is to say, each gallery irrigates its own sector which is determined according to the number of districts. Through main and secondary seguias, the water arrived in each garden through the Koua. The border between each sector is delimited by obstacles in the form of donkeys that allow the water from each gallery to flow into the seguias of its own sector. On the other hand, they play their role as alleys; people and animals can circulate in all the alleys of the six sectors of the palm grove (fig. 30).

Figure 30: A donkey shaped obstacle to direct the flow without disturbing the circulation of the population (Photo. Remini, 2010)

During periods of flood, the population can take the sidewalk which is higher than the lane. These sidewalks play the role of emergency exits. Each garden is equipped with a weir which serves as an overflow to evacuate excess water to the M'zab River. At the level of the palm grove-East, each garden is equipped with a drainage system. It is considered as an overflow which allows the excess of flood water to be evacuated towards the M'zab River (fig. 31).

Figure 31: A system for discharging flood water from a garden in the palm grove of Ghardaïa (Photo. Remini, 2013)

In fact, there is no proper irrigation with flood water since this operation is carried out once or twice a year. On the other hand, the irrigation which is carried out in a period of drought throughout the year by groundwater through the use of wells. In the palm grove there are two types of distribution networks: Flood water network (fig. 32). This type has much wider seguias. Flood water first flows into main seguias, then secondary to multiple seguias. Once the water crosses the Koua and enters the garden, it flows through small earth seguias to promote infiltration. The groundwater distribution network is made up of small seguias that drain water from wells to the plots to be irrigated (fig. 33). In the M'zab valley, wells are called Khottara and are animal-drawn (Fig. 34).

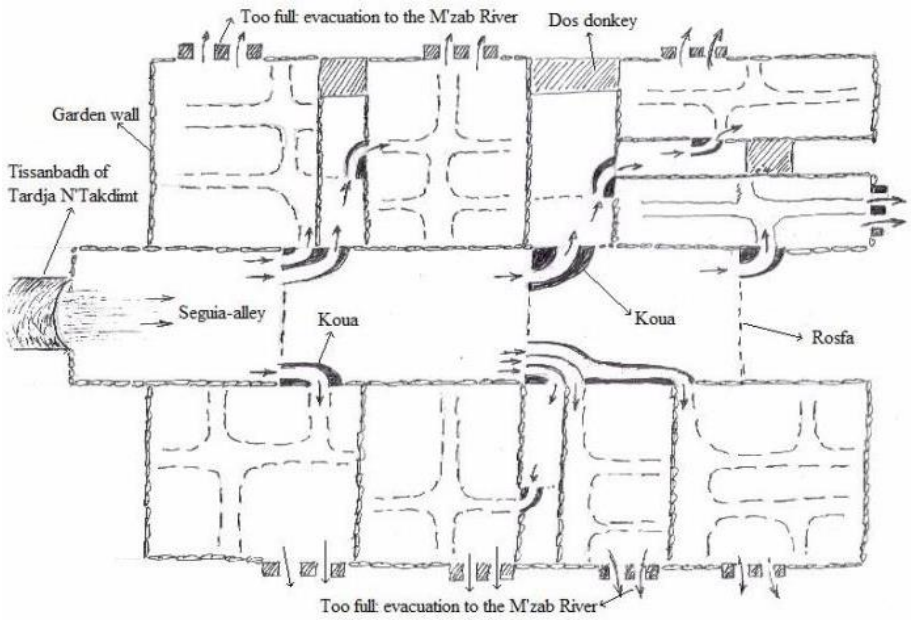


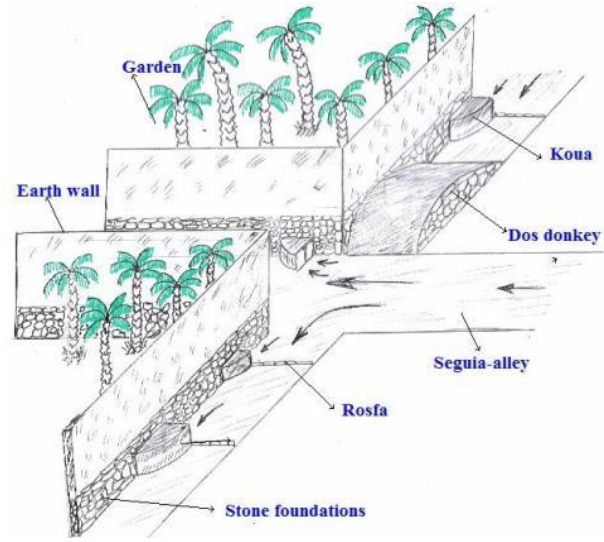
Figure 32: An overview of the floodwater distribution network of the East palm grove of Ghardaia (Photo. Remini, 2020)

Figure 33: An overview of a khottaras water distribution network (Photo. Remini, 2015)

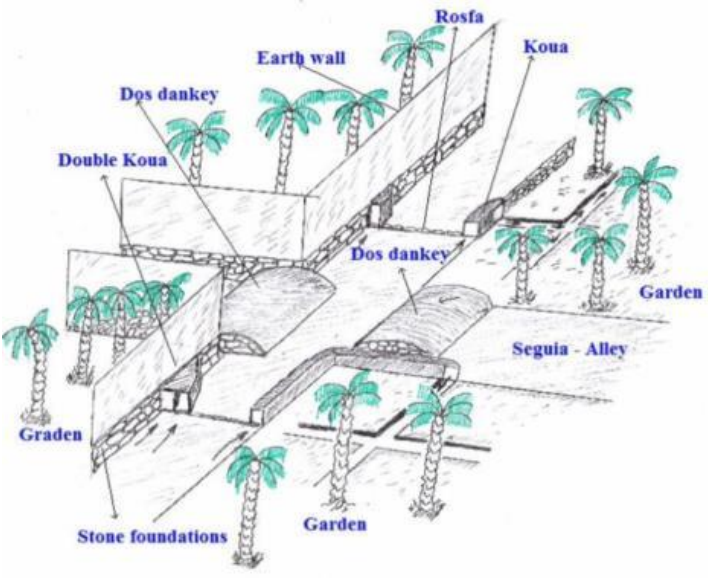
Figure 34: M'zab khottara exists in every garden of the palm grove of the M'zab valley (Photo. Remini, 2008)

DISCUSSIONS: GHARDAIA: THE SPECIFICITY OF A PALM TREE

Capturing, transporting and sharing the raw waters of a flood is the motto applied by the Mozabites for centuries. A whole population that got involved in a mega project just to flood the gardens with floods. Hydro agricultural development has been implemented in the M'zab valley. From upstream to downstream from the palm grove, the water-sharing network is the most complex phase. Composed of ten kilometers of seguia-alley, dozens of overflows (overflow), hundreds of Rosfa, Koua of different dimensions and ten speed bumps, the Ghardaïa floodwater sharing network is unique to the world (fig. 35 (a and b)). Each garden in the East palm grove and whatever its location receives its share of flood water.



a) Simple network



b) Complex network

Figure 35: A view of all the works that constitute the originality of the floodwater distribution network of the Ghardaïa palm grove (Schema, Remini, 2020)

CONCLUSIONS

The sharing of floodwaters among farmers is the last phase of the IRS development in M'zab River. After draining the floodwaters of M'zab River through a system of seguias to the palm grove, the water was divided. Equipped with a Koua system (rectangular opening), a network of seguia-lanes was implemented to distribute the charged water between the gardens. This network is fed by 6 underground galleries, each of them serving a well-defined sector. The dimensions of each gallery are related to the flow of water necessary for the irrigation of its sector. Such an arrangement demonstrates the interest brought by the Ksourian population in raw water irrigation. A unique hydro-agricultural development in the world, unfortunately today, this heritage is in a much degraded state.

ACKNOWLEDGMENTS

I would like to thank the entire Ksour population for helping me finalize this modest work. Without the help of my friends Dahmane and Cheikh, this study will not see the light of day**.**

REFERENCES

BOUAMER K., REMINI B., HABI M., REZZAG K. (2019). The effects of the flood of October 2008 on the water quality in the M'zab valley, Algeria, Journal of Water and Land Development, N°40, Vols I–III, pp.173–180.

KHALIFA A., REMINI B. (2019). The sharing of flood waters in the Ksours of Ghardaia and Berriane (Algeria) hydraulic study. Journal of Water and Land Development. Vols LXV, N° 2, pp. 44 – 57.

OULED BELKHIR C., REMINI B. (2016). Cleanup and valuation of waters of the aquifer of M'zab Valley (Algeria), Journal of Water and Land Development, Vol. 29, N°1, pp. 23-29.

REMINI B., OULED BELKHIR C. (2019). The ancestral system of sharing the flood waters of the Metlili oasis (Algeria): a forgotten hydraulic heritage! Larhyss Journal, N°40, Dec, pp. 213-247.

REMINI B. (2019). The oasis of El Guerrara (Algeria): irrigation and recharge of groundwater provided by the floods. Larhyss Journal, N°40, Dec, pp. 213-247.

REMINI B. (2018). The foggaras of the oasis of Ghardaia (Algeria): the sharing of flood waters, Larhyss Journal, N° 36, pp. 157-178.

REMINI B., ACHOUR B., OULED BELKHIR C., BABA AMAR D. (2012). The M'zab foggara: an original technique for collecting the water rising, Journal of Water and Land Development, Vols. I-VI, No 16, pp. 49–53.

ZEGAIT R., REMINI B. OULED BELKHIR C. (2018). Irrational management of water resources in southern Algeria (Case of the M'zab valley), Journal International Sciences et Technique de l'Eau et de l'Environnement, Vol. III, N°1, April, pp. 223-231.

REMINI B. (2020). When the Oasian genius tamps the floods: ancestral IRS Development of Touzouz River (M'zab valley, Algeria). Larhyss Journal, N° 41, March, pp.261-295.